ALKALINITY

FACT SHEET

See related Fact Sheets: Acronyms & Abbreviations; Glossary of Terms; Cost Assumptions; Raw Water Composition; Total Plant Costs; and WaTER Program.

1. CONTAMINANT DATA

A. Chemical Data: Alkalis are substances that when dissolved in water turn litmus paper blue and include the soluble CO_3^{-2}, HCO_3^-, and OH^- salts of Ca, Mg, K, and Na. Alkalinity is the quantitative capacity of water to neutralize an acid, or the measure of how much acid can be added to a liquid without causing a significant change in pH. Water does not have to be strongly basic (high pH) to have high alkalinity. Generally, in the water industry, the three types of alkalinity include: CO_3^{-2}, HCO_3^-, and OH^-. Total alkalinity is the sum of these three types and is expressed in mg/L of $CaCO_3$ equivalent. There are three different tests used for measuring alkalinity, usually performed in this order: pH (to obtain OH^- alkalinity), phenolphthalein test (to obtain OH^- and CO_3^{-2} alkalinity), and methyl orange test (to obtain total alkalinity).

B. Source in Nature: In the environment, alkalinity in the soil (limestone) and ground and surface waters is a combination of the naturally occurring alkalis: CO_3^{-2}, HCO_3^-, and OH^- salts of Ca, Mg, K, and Na. Most natural waters have an alkalinity in the range of 10 to 500 mg/L. Wastewater is normally alkaline, receiving alkalinity from the water supply, groundwater, and materials added during domestic use including detergents and soap-based products which are alkaline. Acid rain also contributes to the alkalinity of waters. Alkalinity is often related to hardness. Ca^{+2} and Mg^{+2} ions are primarily responsible for hardness. However, in most waters, alkalinity and hardness have similar values because the CO_3^{-2} and HCO_3^- responsible for total alkalinity are usually brought into the water in the form of $CaCO_3$ or $MgCO_3$. The three forms of alkalinity are also strongly related to the amount of carbon dioxide present in the water.

C. SDWA Limits: Alkalinity is not a primary or a secondary drinking water contaminant. No federal limits exist.

D. Health Effects of Contamination: Alkalis, when dissolved in water, create a bitter taste and a slippery feel. Highly alkaline waters, above pH 7.0, can cause drying of the skin. Alkalinity is important for fish and aquatic life because it protects or buffers against rapid pH changes and makes water less vulnerable to acid rain, protecting a major source of human consumption.

2. REMOVAL TECHNIQUES

A. USEPA BAT: BAT's are not assigned.

B. Alternative Methods of Treatment: Generally, there are three processes for reducing alkalinity: lime softening, Cl^- anion exchange (dealkalization), and weak acid cation exchange (dealkalization).

! Lime softening to reduce alkalinity results in a partial reduction of water hardness, and uses controlled amounts of $Ca(OH)_2$ in sufficient quantity to raise the pH to about 10 to precipitate CO_3^{-2} hardness, after which the precipitated alkalinity is filtered out. The precipitated alkalinity is then removed as a sludge. Benefits: lower capital costs; proven and reliable. Limitations: operator care required with chemical usage; sludge disposal

! Anion IX to reduce alkalinity uses charged anion resin to exchange acceptable ions from the resin for the undesirable alkalinity in the water. Benefits: acid addition, degasification, and repressurization is not required; effective; well developed. Limitations: pretreatment lime softening may be required; restocking of regenerate supply; regular regeneration; concentrate disposal.

! Cation IX to reduce alkalinity uses charged cation resin to exchange acceptable ions from the resin for hardness ions (Ca and Mg) plus some of the undesirable alkalinity in the water. Benefits: most suitable for low flows; therefore, cost curves are not presented in this Fact Sheet. Limitations: requires a hardness-to-alkalinity ratio greater than 1.

C. Safety and Health Requirements for Treatment Processes: Personnel involved with demineralization treatment processes should be aware of the chemicals being used (MSDS information), the electrical shock hazards, and the hydraulic pressures required to operate the equipment. General industry safety, health, and self protection practices should be followed, including proper use of tools.

3. BAT PROCESS DESCRIPTION AND COST DATA

General Assumptions: Refer to: Raw Water Composition Fact Sheet for ionic concentrations; and Cost Assumptions Fact Sheet for cost index data and process assumptions. All costs are based on *ENR*, PPI, and BLS cost indices for March 2001. General sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal are not included.

Bureau of Reclamation, Technical Service Center
Water Treatment Engineering and Research Group, D-8230
PO Box 25007, Denver CO 80225 (303) 445-2260
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3A. Lime Softening:

Process - Lime softening uses a chemical addition followed by an upflow SCC to accomplish coagulation, flocculation, and clarification. Chemical addition includes adding $Ca(OH)_2$ in sufficient quantity to raise the pH while keeping the levels of alkalinity relatively low, to precipitate CO_3^{-2} hardness and reduce the solubility of alkalinity. Alkalinity precipitates as sludge. In the upflow SCC, coagulation and flocculation (agglomeration of the suspended material, including alkalinity, into larger particles), and final clarification occur. In the upflow SCC, the clarified water flows up and over the weirs, while the settled particles are removed by pumping or other collection mechanisms (i.e. filtration).

Pretreatment - Jar tests to determine optimum pH and alkalinity for coagulation, and resulting pH and alkalinity adjustment, may be required. Optimum pH is about 10.

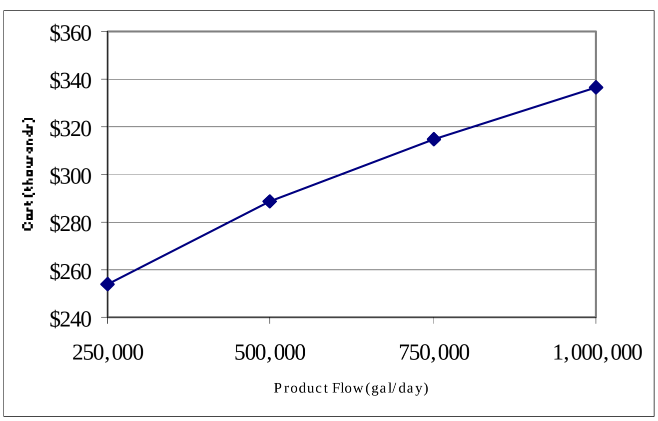
Maintenance - A routine check of chemical feed equipment is necessary several times during each work period to prevent clogging and equipment wear, and to ensure adequate chemical supply. All pumps, valves, and piping must be regularly checked and cleaned to prevent buildup of carbonate scale, which can cause plugging and malfunction. Similar procedures also apply to the sludge disposal return system, which takes the settled sludge from the bottom of the clarifier and conveys it to the dewatering and disposal processes.

Waste Disposal - There are three disposal options for alkaline sludge: incineration, landfill, and ocean disposal.

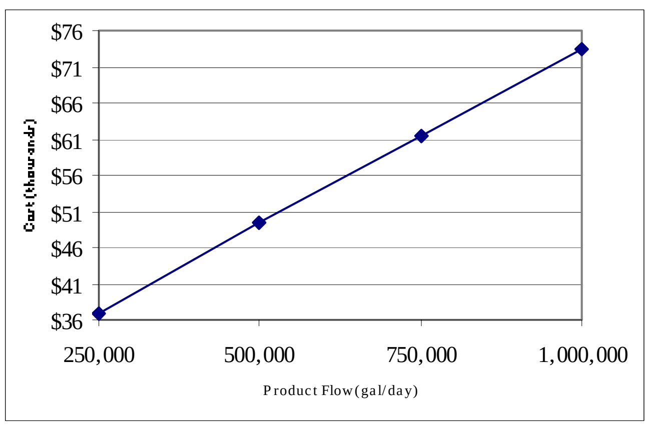
Advantages -
- Other heavy metals are also precipitated; reduces corrosion of pipes.
- Proven and reliable.
- Low pretreatment requirements.

Disadvantages -
- Operator care required with chemical handling.
- Produces high sludge volume.

BAT Equipment Cost*



BAT Annual O&M Cost*



*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.

3B. Ion Exchange:

Process - In solution, salts separate into positively-charged cations and negatively-charged anions. Deionization can reduce the amounts of these ions. IX is a reversible chemical process in which ions from an insoluble, permanent, solid resin bed are exchanged for ions in water. The process relies on the fact that water solutions must be electrically neutral, therefore ions in the resin bed are exchanged with ions of similar charge in the water. As a result of the exchange process, no reduction in ions is obtained. In the case of alkalinity reduction, operation begins with a fully recharged resin bed, having enough negatively or positively charged ions to carry out the ion exchange. Usually a polymer resin bed is composed of millions of medium sand grain size, spherical beads. As water passes through the resin bed, the negatively or positively charged ions are released into the water, being substituted or replaced with the alkalinity anions in the water (ion exchange). When the resin becomes exhausted of charged ions, the bed must be regenerated by passing a strong, usually NaCl (or KCl), solution over the resin bed, displacing the alkalinity ions. Many different types of anion and cation resins can be used to reduce dissolved alkalinity concentrations. The use of IX to reduce concentrations of alkalinity will be dependant on the specific chemical characteristics of the raw water.

Cation IX, commonly termed water softening, can be used with low flows (up to 200 GPM) and when the ratio of hardness-to-alkalinity is greater than 1.

Pretreatment - Guidelines are available on accepted limits for pH, organics, turbidity, and other raw water characteristics. Pretreatment may be required to reduce excessive amounts of TSS which could plug the resin bed, and typically includes media or carbon filtration.

Maintenance - The IX resin requires regular regeneration, the frequency of which depends on the raw water characteristics and the alkalinity concentration. Preparation of the NaCl solution is required. If utilized, filter replacement and backwashing will be required.

Waste Disposal - Approval from local authorities is usually required for the disposal of concentrate from the regeneration cycle (highly concentrated alkaline solution); occasional solid wastes (in the form of broken resin beads) which are backwashed during regeneration; and if utilized, spent filters and backwash waste water.

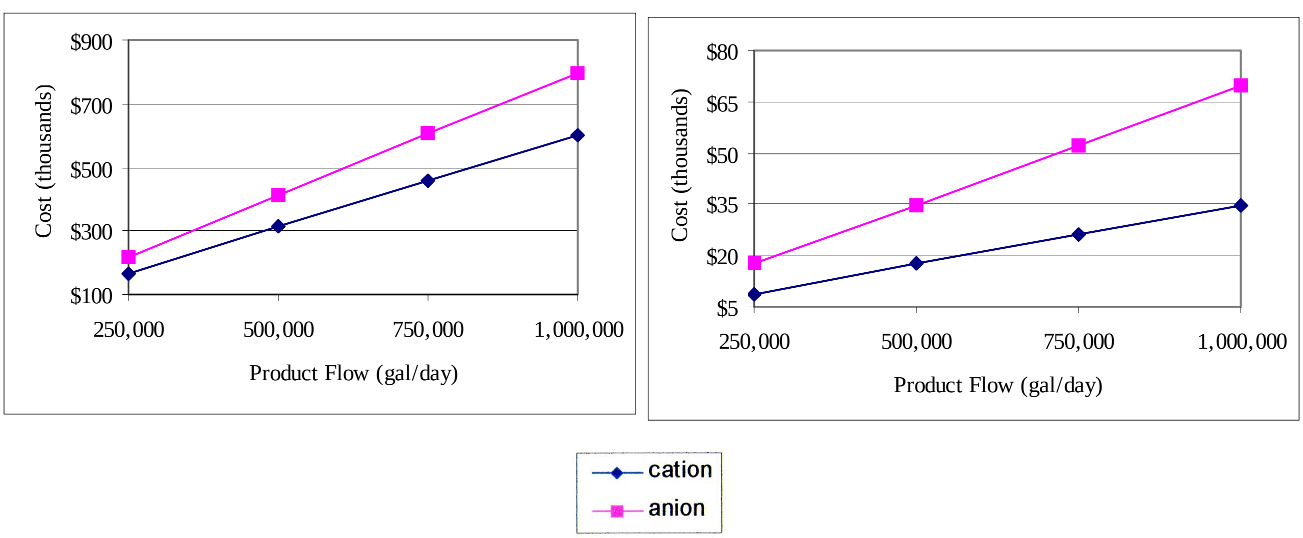
Advantages -

- Acid addition, degasification, and repressurization is not required.
- Ease of operation; highly reliable.
- Lower initial cost; resins will not wear out with regular regeneration.
- Effective; widely used.
- Suitable for small and large installations.
- Variety of specific resins are available for removing specific contaminants.

Disadvantages -

- Pretreatment lime softening may be required.
- Requires salt storage; regular regeneration.
- Strongly basic anion resins are susceptible to organic fouling; reduced life; thermodynamically unstable.
- Concentrate disposal.
- Usually not feasible with high levels of TDS.
- Resins are sensitive to the presence of competing ions.

BAT Equipment Cost* **BAT Annual O&M Cost***



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